III.C.

CONVENTIONAL METHODS OF TRAIN OPERATIONS AND POSITIVE TRAIN CONTROL SYSTEMS

The railroad industry, with advocacy from the Federal sector, has pursued the development and implementation of communications-based train control systems for more than 15 years. The initial objective was to develop a train control system at less cost than conventional train control systems that provided equivalent or greater safety of train operations and business benefits. At least 12 projects have been undertaken during this time to develop communications-based train control systems, now colloquially termed Positive Train Control (PTC) systems. Three projects were unsuccessful, two of which were abandoned and one currently in suspension, because of prohibitive costs. Nine of the projects are presently in various stages of development.

The developing PTC systems are works in progress undergoing evolving change as technology develops. They appear to fall into three categories: those that will become stand alone systems; those that will be integrated systems; and those that will be overlay systems.

A PTC system of the stand alone type will not only augment the existing signal system but will absorb its functionality to the extent wayside signals may safely be removed. Safety computers at a central office, on the wayside and on board each locomotive will enforce the proper spacing of trains, all speeds and stop where a stop is required. Stand alone PTC systems will become the method of train operations.

PTC systems of the integrated type will be so interconnected with the existing signal system that its functionalities will be extended to equipment on board each locomotive that will enforce all speed and stop requirements prescribed by both the PTC and signal system. The existing method of train operations may or may not change.

PTC systems of the overlay type will provide for, among other things, enforcement of all speed and stop requirements while utilizing the existing system as the primary method of train operations.

Methods of Train Operations

The three major methods of train operations on main tracks in the U.S. are: by signal indications; train orders; and manual block rules. The PTC systems under development are centered on one or more of these methods of operation.

Operations by Signal Indications

Operations by signal indications occur at interlockings, in traffic control systems and automatic block signal systems on two main tracks arranged for movement with the current of traffic. Trains having authority to enter these systems are governed by the indications of signal aspects that are arranged to provide for movement at maximum authorized speeds; provide sufficient distance to slow a movement in approach to the point where speed is to be reduced; and provide sufficient distance to stop a movement at the point where a stop is required. Absent control devices that supplement the signal systems to enforce maximum authorized speed and speed reductions (e.g., automatic train control or automatic trainstop), compliance is dependent upon the locomotive engineer to properly control the speed of a train. With or without supplementary control devices, it is dependent upon the locomotive engineer to stop a train at a point where a stop is required.

Operations by Mandatory Directives

Operations by mandatory directives may occur in either automatic block signal territory or non signaled territory. Mandatory directives are orders that affect the movement of trains and are identified on various railroads as train orders, track warrants, track permits, track bulletins, block authorities and Form D. Mandatory directives provide the authority for the movement of a train and may be used for the protection of roadway workers and on track equipment.

Mandatory directives are orally issued by the dispatcher to a train crew member who must repeat the directives back to the dispatcher for verification of correctness. Mandatory directives authorize the movement of a train between specific points and provide instructions for meeting or passing other trains, speed restrictions and other special conditions. Where automatic block signals supplement operations by mandatory directives, indications of signal aspects furnish train crew members information about block conditions in advance and provide sufficient spacing to slow or stop a train as may be required. The dispatcher is relied upon to issue mandatory directives that provide for the safe movement of trains. It is dependent upon train crew members to comply with both the instructions contained in mandatory directives and signal indications of a block signal system and to control the speed of a train and stop where a stop is required.

Operations by Manual Block Rules

Manual block rules are used for the movement of trains on designated portions of several railroads. In a manual block system the railroad is segmented into blocks of designated lengths. Mandatory directives are issued by a block operator or dispatcher that provide authority for a train to enter a block or blocks. No train may be permitted to enter a block occupied by a passenger train or an opposing train; a passenger train may not enter a block occupied by another train; but a freight train may follow a freight train into a block provided the following train proceeds prepared to stop in one-half the range of vision but not exceeding 20 mph. Block operators are relied upon to assure each block is unoccupied before permitting a train to enter the block. It is dependent upon train crew members not to enter a block without authority, to properly control the speed of a train and stop where a stop is required.

Other Methods of Operation

For branch lines, industry tracks, other auxiliary tracks and yards various methods of operations are employed for the movement of trains. Voice rules and yard rules are utilized in yard operations and switching services on industry tracks. Yard limit rules are utilized on main tracks extending through yards and stations and on branch lines. Timetable special instructions are utilized on branch lines, industry tracks and in conjunction with mandatory directives on main tracks. All of these methods of operations rely upon dispatchers, operators, yardmasters and train crew members to be learned in the rules governing the methods of operations, issue succinct orders orally, and comply with all the requirements. It is dependent upon train crew members to properly control the speed of a train and stop where a stop is required.

REQUIREMENTS FOR SIGNAL AND TRAIN CONTROL SYSTEMS

Federal requirements exist that prohibit the operation of a freight train at a speed of 50 or more miles per hour or a passenger train at a speed of 60 or more miles per hour unless a manual block system or a block signal system is installed; and prohibits the operation of any train at 80 or more miles per hour unless an automatic cab signal, trainstop or train control system is installed.

An automatic block signal system or a traffic control system is necessary to support the installation of automatic cab signal, trainstop or train control systems. Cab signal, trainstop and train control devices are installed on board locomotives and, accordingly, supplement the block signal or traffic control system. Track circuits or devices along the wayside are used to communicate signal system status to the on board equipment.

Automatic cab signals are inductively connected to track circuits and convey aspects on board that indicate the condition of the block being traversed and the blocks in advance. No enforcement is provided by automatic cab signals and train crew members are relied upon to comply with the indications displayed, properly control the speed of a train and to stop where a stop is required.

Automatic train control devices augment automatic cabs signals and provide enforcement of speeds associated with cab signal indications. When a more restrictive cab signal indication is obtained, the locomotive engineer must immediately take action to reduce the train speed to that prescribed by the signal indication or the train control device will initiate a brake application to stop the train. The most restrictive cab signal indication permits a speed not exceeding 20 mph. It is dependent upon the locomotive engineer, at speeds of 20 mph or less, to properly control the speed of the train and stop where a stop is required.

Continuous inductive automatic trainstop devices also augment automatic cab signals but do not provide enforcement of speeds. When a more restrictive cab signal is obtained, the locomotive engineer must acknowledge the restrictive cab signal within a prescribed period of time or the trainstop device will initiate a brake application to stop the train. The locomotive engineer is relied upon to properly control the speed of a train after acknowledging a restrictive cab signal and to stop the train where a stop is required.

Intermittent inductive automatic trainstop devices may be utilized without cab signals by being coupled by inductors to the wayside signal system (i.e., at each signal location). When a train passes a wayside signal displaying a restricting aspect, the locomotive engineer must acknowledge the restrictive indication within a prescribed period of time or the trainstop device will initiate a brake application to stop the train. It is dependent upon the locomotive engineer to properly control the speed of a train after acknowledging a restricting wayside signal indication and to stop the train where a stop is required.

PTC PREVENTABLE ACCIDENTS

A review of the requirements for reporting accidents identified 63 causal factors of accidents that are potentially PTC preventable. The RSAC PTC Working Group assigned a team to identify the PTC preventable accidents in which those causal factors were present. The accident review team was composed of representatives from railroad management, labor and FRA and had many years' experience in railroad operations, signal and train control systems and research and development.

The accident review team reviewed about 6400 accidents selected from over 25,000 accidents contained in FRA's database for the years 1988 through 1997. Only accidents that occurred on the main track or sidings were reviewed. Four PTC design concepts based on the functionalities of three current projects and the Advanced Train Control Systems (ATCS) Level 40 specifications were used to identify the PTC preventable accidents. The three PTC systems that were used to identify PTC preventable accidents were the Amtrak Incremental Train Control System (ITCS) project; the UP/BNSF Positive Train Separation (PTS) project (now in suspension); and the BNSF Enhanced Proximity Warning System (Train Guard).

The ATCS Level 40 specifications and the three PTC projects were utilized as four design concepts on the basis of their functionalities. The following descriptions of these concepts includes references to other specifications and systems. However, for purposes of identifying PTC Preventible accidents, the functions provided by the concepts may contain additional or fewer functions than those systems or specifications. ATCS Level 40 was considered the supreme concept with most functionalities, followed in descending order by ITCS, PTS and Train Guard, Levels 4, 3, 2 and 1, respectively. Each accident was reviewed and, by the process of concensus, placed in the level of PTC concept deemed capable of preventing that type of accident.

Although the capabilities of the PTC systems in terms of the type of accidents they prevent are hierarchical in nature, the fundamental design concepts of the representative systems referenced are decidedly different. That is, a lower level system is not necessarily a subset of a higher level system. For example, Train Guard (level 1 concept) is not a subset of PTS (level 2 concept). Similarly, although PTS at level 2 could be considered a subset of level 4, it shares very little of the technology employed in ITCS (level 3 concept).

From review of approximately 6400 accidents, the accident review team identified 685 PTC preventable accidents and 267 accidents that would have been diminished in risk had PTC been in effect. The results of this review for each level is as follows:

Concept	PTC Preventable	Risk Diminished by PTC	Total
4	685	267	952
3	627	31	658
2	568	22	590
1	393	82	475

The results show that 952 of the 6400 accidents would have been prevented or the risk diminished by a Level 4 PTC system; 658 of the 952 accidents would have been prevented or the risk diminished by a Level 3 PTC system; 590 of the 952 accidents would have been prevented or the risk diminished by a Level 2 PTC system; and 475 of the 952 accidents would have been prevented or the risk diminished by a Level 1 PTC system.

The accidents identified by the accident review team's study were provided to the Volpe National Transportation Systems Center for incorporation into a Corridor Risk Analysis Model where the costs and casualties of the PTC preventable accidents will be identified.

The results of the accident review team's study further confirms the capabilities of the various PTC systems under development to intervene before a catastrophic incident occurs. In addition, the study provides an initial comparison of the capability of different PTC systems.

POSITIVE TRAIN CONTROL PROJECTS

Background

In late 1983, the Canadian National, British Columbia, Canadian Pacific, Burlington Northern, Norfolk Southern, Seaboard System, Union Pacific and Southern Pacific railroads jointly agreed to support an endeavor to identify operating requirements for a communications-based train control system. In 1984, under the auspices of the Association of American Railroads (AAR) and the Railway Association of Canada (RAC), the Advanced Train Control System (ATCS) project office was established. A technical consulting firm, ARINC, was retained to perform a technology assessment and design the system architecture with oversight provided by railroad representatives.

The development of the specifications for ATCS took more than three years to complete in an open forum process with railroads, vendors and FRA participating in component drafting committees. The specifications are detailed enough to ensure component interoperability and system safety without limiting vendor ingenuity. The ATCS Specifications are currently managed by the AAR.

Previous PTC Projects

Overview of the Advanced Train Control System (ATCS)

ATCS was built using off-the-shelf equipment and computers and was considered to be comprised of five major systems: the Central Dispatch System, On-Board Locomotive System, On-Board Work Vehicle System, Field System, and Data Communications System. Each of the systems fully complied with the ATCS Specifications in an open architecture.

The Central Dispatch System consisted of two subsystems - a console from which the dispatcher managed train operations that was linked to the ATCS system, and a the Central Dispatch Computer. The console provided both an information display and data entry capabilities for the dispatcher. The Central Dispatch Computer was actually two interlinked computers, one that processed information to and from the dispatcher and other ATCS components, and the other that managed train movements with the objective of guaranteeing safe operations and minimizing train delays.

The Locomotive System also consisted of two subsystems - the locomotive display and the on-board computer (OBC). The display provided the interface between the engineer and ATCS; it displayed information about location, route, speed, speed restrictions, maintenance-of-way work locations, messages concerning the train movement, controlled point status and dispatcher advisories. The display contained a terminal from which the engineer could send and confirm information digitally with the dispatcher, field offices and other vehicles. The OBC was equipped a transponder interrogator and a track database. The OBC performed on-board data processing and safety checking and handled data transmitted to and from the dispatcher, other locomotives, maintenance-of-way employees, and coordinated location tracking, enforcement, movement authorities switch monitoring and control, and health reporting.
The Work Vehicle System consisted of two subsystems - a display that provided the interface between a maintenance-of-way foreman and ATCS which permitted the foreman to communicate digitally with the dispatcher or other vehicles and to be aware of nearby track activity and a Track Forces Terminal that

performed data processing and safety checking to manage the movement of equipped work vehicles through the ATCS system.

The Field System consisted of wayside interface units (WIU) that provided remote control and monitoring of field devices. The WIUs performed internal data processing and error-checking, commanded the movement of controllable devices (e.g., moveable bridges or power-operated switches), monitored non-controllable devices and highway rail grade crossing signals. In addition, transponders were placed along the railroad at strategic points (e.g., controlled points, approach to controlled points, interlockings, etc.) for location determination. An interrogater on-board the equipped trains read each transponder which provided precise location, track identification and distance to the next transponder. At each transponder, the OBC reset a tachometer that was used to provide location in the intervening distances between transponders.

The Data Communications System was a digital data radio network operating in the UHF radio spectrum and controlled from the Central Dispatch Office. As in typical systems, the communications hardware consisted of front end processors (FEP), cluster controllers (CC), base communications packages (BCP) and mobile communications packages (MCP). The FEP is the major entry point from the Central Dispatch Computer into the ATCS ground network and performs train location functions and protocol conversions. Each FEP is connected to serveral CCs. The CC is a routing node in the ground network, manages a base station and performs functions similar to the FEP but over a smaller geographical area (e.g., routing of messages to and from trains or wayside devices under its control). The BCP provides the interface to the ATCS radio frequency and may contain one or more base station radios (each on different channel pairs). Base stations may be connected to the Central Dispatch Office by land lines, leased lines, microwave, fiber optics or radio. The MCP is configured to perform an interface between the RF network and the locomotive computer and display; an interface between an RF network and a WIU; and/or an interface between the ground network and a wayside equipment controller (e.g., code line messages). An MCP is required at each wayside equipment location and on each locomotive and maintenance-of-way vehicle to transmit and receive messages. The ATCS data transmitted over the network included message protocols that required a handshake (closed loop) in order to become effective or be implemented.

In 1990, the Canadian National, after considerable testing in British Columbia, installed ATCS on two test beds in Ontario. The test beds were utilized for more than five years to successfully develop, test and prove ATCS technology in both commuter operations and freight railroad operations before being abandoned.

Overview of the Advanced Railroad Electronics System (ARES)

ARES was conceived in 1984 as an alternate to ATCS. Following considerable study, the Burlington Northern retained Rockwell International in 1986 to develop and test ARES in a real railroad environment. ARES utilized Rockwell (now WABCO Railway Electronics) built equipment and was considered to be comprised of three major segments: the Control Segment, the Data Segment and the Vehicle Segment. Each of the segments were built to specifications developed by the Burlington Northern and Rockwell which are proprietary.

The Control Segment consisted of a console from which dispatchers could monitor the positions and velocities of all equipped and unequipped vehicles in traffic control territory, automatic block signal territory and non-signaled territory. The Control Segment produced traffic plans, displayed activity at three levels and information about consists, crews, and work orders for each train. In addition, the Control Segment monitored activity to ensure vehicles followed proper operating procedures and warned the dispatcher of violations of limits of speed and authority. Further, the Control Segment performed conflict checking of track warrants and other movement authorities before they were transmitted to trains and maintenance-of-way employees and monitored progress of the meet/pass plan and communicated corrective action to equipped trains.

The Data Segment consisted of a communications network that provided data paths in the VHF radio spectrum between the mobile equipment, wayside equipment and the control center. It consisted of equipment similar to that of ATCS: FEPs, CC, BCPs and MCPs. Digital data messages were routed by the FEPs and CCs to BCPs at base stations. The base stations were a backbone of microwave towers with redundant VHF transmitters and receivers spaced at an average of 25 miles apart along the main tracks. The base station BCPs provided an interface to mobile vehicles for movement authorities, restrictions, and work orders and to wayside interface units to monitor and communicate the status of hand-operated switches, power-operated switches and signals through the network to the dispatcher.

The Vehicle Segment included both locomotives and maintenance-of-way vehicles. Locomotives were equipped with a receiver for Navstar Global Positioning System (GPS) signals to calculate train position and speed, a display that informed the crew members about movement authorities, the route ahead, work along the route, and the health of locomotives in the consist. The Vehicle Segment was equipped to apply a full service brake application if the crew was disabled, the train violated its movement authority or speed requirements. The maintenance-of-way vehicles were equipped with a GPS receiver to calculate speed and location, a device to digitally communicate with the dispatcher, and a printer to receive warrants, bulletins and work time in the field. The Vehicle System was equipped with a track database and periodically reported position and speed to the Control Segment. The ARES message protocols also included requirement of a handshake (closed loop) in order to become effective or be implemented.

ARES was implemented on a test bed of 230 miles of track in the Mesabi Iron Range in late 1986. The protype equipment was installed on 17 locomotive and 3 maintenance-of-way vehicles. The test bed was utilized continuously for more than five years to successfully develop, test and prove ARES technology before being terminated.

Overview of the Positive Train Separation (PTS) Project

In 1994, the Union Pacific and Burlington Northern (now Burlington Northern Santa Fe) jointly embarked upon development of a Positive Train Separation (PTS) system. Harris Corporation (now GE Harris Railway Electronics) was retained to develop and test PTS. PTS was considered to have three major segments: the Locomotive Segment; the Communications Segment; and the Server Segment. PTS utilized the communications network that exists on each railroad with only minimal changes. The Locomotive Segment and Server Segment were built to UP/BNSF and GE Harris specifications in an open architecture.

The Locomotive Segment consisted of an on-board computer (OBC) with a cab display. Each locomotive was equipped with a GPS receiver, a differential GPS (DGPS) receiver and a mobile communications package (MCP), all interconnected to the OBC. The OBC contained a track database and performed data processing to monitor location, calculate braking curves, receive authority limits, apply the brakes if the authority limits were projected to be exceeded, receive speed limits, apply the brakes if the speed limit was or projected to be exceeded, transmit position data and transmit violation messages. Buttons on the bezel of the display provided means by which the locomotive engineer could digitally communicate with the dispatcher.

The Server, a computer, was interfaced to a computer aided dispatching system console from which a dispatcher could monitor and direct train movements and interfaced to the communications segment for transmitting and receiving data to and from trains. The Server generated movement authorities on the basis of those issued by the dispatcher and then established and transmitted authority limits to trains, established and transmitted speed limits to trains, received position data from trains and received violation messages.

The communications segment on the UP provides data paths in the UHF radio spectrum between the mobile equipment, wayside equipment and the control center. The communications segment on the BNSF provides data paths in the VHF radio spectrum between the mobile equipment, wayside equipment and the control center. Both communications networks consists of equipment similar to that described for ATCS: FEPs, CC, BCPs and MCPs. The message protocols of both systems contained the requirement for a handshake (closed loop) in order to become effective or be implemented.

PTS was installed in a testbed extending from Blaine, Washington, to Pasco, Washington, on the BNSF, and between Vancouver, Washington, and Hinkle, Oregon, on the UP, a total distance of about 865 track miles. The segment between Tacoma, Washington, and Vancouver, Washington, is joint trackage on which base stations operating in the UHF radio spectrum was installed in order to achieve PTS interoperability between trains of the two railroads. PTS prototype equipment was installed on 8 locomotives, 4 from each carrier. The test bed was utilized for more than four years to successfully develop, test and prove PTS technology. The PTS project is currently suspended.

CURRENT PTC PROJECTS

Overview of the Incremental Train Control System (ITCS)

In 1995, the Michigan Department of Transportation, in cooperation with Amtrak and Harmon Industries, was granted funding by the FRA for a demonstration of a high-speed positive train control system on an Amtrak line extending between Porter and Kalamazoo, Michigan. The proposed system is identified as ITCS and consists of three major segments - the Wayside Equipment Segment, the Communications Segment and the Locomotive Segment. Each of the segments were built to specifications developed by Amtrak and Harmon Industries which are proprietary

The Wayside Equipment Segment is comprised of wayside interface units (WIU) at each controlled point, intermediate signal, electrically-locked hand-operated switch and highway rail grade crossing signal. The WIUs monitor switch position, track circuit occupancy and signal aspects displayed in the traffic control system and the status of highway rail grade crossings.

The Communications Segment consists of two parts - a spread spectrum wide local area network (WLAN) that connects the WIUs to wayside interface unit-servers (WIU-S) that in turn are interfaced to broadcast digital data messages in the UHF radio spectrum. There are 8 WIU-Ss spaced about 10 miles apart along the railroad. WIUs are slaves to WIU-Ss and continuously report via the WLAN the status of the device(s) being monitored to their assigned WIU-S. The WIU-S broadcasts (open loop) the status reported by the WIUs once every six seconds. Each WIU-S is provided with a track database for the territory it serves including maximum authorized speed and speed restrictions. An office to wayside land line provides means for the control operator to issue or void temporary speed restrictions to the track databases of the WIU-Ss.

The Locomotive Segment consists of an on-board computer (OBC) and cab display. The cab display provides the man-machine interface between ITCS and the locomotive engineer by continuously displaying the maximum authorized speed, actual speed, distance to targets, type of targets and target speeds. The OBC stores a database of signal indications, track curvature, gradients, mileposts, civil speed limits, speed restrictions and the locations of all devices with which it may be required to communicate. The OBC continuously calculates braking distances to targets, monitors current speed and upcoming speeds and initiates a full service brake application if the maximum authorized speed is violated or the train is not properly slowed for an upcoming speed restriction or requirement to stop. The OBC establishes a session with each WIU-S when it enters its zone of coverage, verifies that it has an updated track database and expects to receive a WIU-S broadcast every six seconds. The OBC can miss two broadcasts without adverse affects but a missed third broadcast (18 to 20 seconds elapsed time) results in the OBC initiating an automatic brake application, stopping the train, thus adequately compensating for the open loop broadcast architecture.

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ITCS is designed to prestart highway rail grade crossing signals at train speeds above 80 mph. The grade crossing signals have conventional approach track circuits designed to provide 30 seconds warning for train speeds of 80 mph. The approach to an active grade crossing system is determined by the OBC from the track database. At speeds above 80 mph, a session is then established via the WIU-S with the crossing WIU and the OBC provides an estimated time of arrival. If the crossing WIU indicates it is armed and functioning as intended, the train may proceed at speed and the crossing will provide the required 30 seconds warning. The estimated time of arrival at the crossing is updated every 5 seconds until the train reaches a point 30 seconds from the crossing. If a crossing does not arm or indicates it is not functioning as intended, the OBC will initiate a full service brake application to slow the train before it reaches the crossing. ITCS will restrict the movement of subsequent trains at a failed crossing to 15 mph until the crossing device is repaired.

ITCS was installed in a testbed on Amtrak's Michigan Line between milepost 175 and milepost 195, a distance of about 20 miles. Two trainsets, in push-pull configuration, were equipped with ITCS. Since 1995, the testbed has been utilized to develop, test and prove ITCS technology. ITCS is scheduled to be implemented in revenue service in mid 1999 between milepost 145, near Kalamazoo, Michigan, and milepost 216, near New Buffalo, Michigan, a distance of about 71 miles.

Overview of the Advanced Civil Speed Enforcement System (ACSES)

Amtrak has received FRA approval to install ACSES in the Northeast Corridor (Final order of particular applicability, FR39343, July 22, 1998). ACSES will augment the 4-apect cab signal system to nine aspects and will utilize transponders of a European design to achieve maximum authorized speeds up to 150 mph, enforcement of civil speeds, temporary speed restrictions and absolute stop. Amtrak has retained Parsons Brinckerhoff to develop, test and implement ACSES using off-the-shelf equipment in an open architecture.

The existing cab signal and train control system utilizes a 100 Hz coded carrier transmitted in the rails to provide for speeds of 20 mph (Restricted Speed), 30 mph, 45 mph and maximum authorized speeds up to 125 mph at code rates of 0, 75, 120 and 180 pulses per minute, respectively. The 9-aspect system will be achieved by the addition of a new 250 Hz coded carrier that, in combination with the 100 Hz coded carrier will provide aspects for enforceable speeds of 80 mph, 125 mph and 150 mph. The addition of a new code rate, 270 pulses per minute, will provide aspects for enforceable speeds of 60 mph and 100 mph.

Transponders will be placed in the approach to speed-restricted zones. The transponders will provide data to on-board equipment that includes distance to the beginning of a speed restriction, type of speed restriction, target speed, average grade to the restriction, distance to the next transponder and message verification information. The on-board computer, through data from a tachometer, will monitor the train's performance and, if necessary, initiate an automatic brake application to prevent entering the speed restriction at a speed above that prescribed.

Transponders will also be placed in the approach to interlockings to provide for enforcement of absolute stop when the interlocking signal displays an aspect requiring stop.

ACSES will permit the continued operation at existing speeds of all the users of the Northeast Corridor including Conrail, Southeastern Pennsylvania Transportation Authority, New Jersey Transit, and Providence and Worcester railroads.

The intial installation of ACSES is underway between New Haven, Connecticut, and Boston, Massachusetts.

Overview of the New Jersey Transit Project (NJT)

A project similar to and compatible with Amtrak's ACSES system is planned for installation on 132 route miles of the New Jersey Transit (NJT). NJT also connects with Amtrak in New Jersey and operates more than 300 trains daily over that part of the Northeast Corridor extending between New York, New York and Philadelphia, Pennsylvania and over the Atlantic City Line extending between Philadelphia, Pennsylvania and Atlantic City, New Jersey.

Like ACSES, the NJT system will be transponder-based to provide for enforcement of civil speeds, temporary speed restrictions and absolute stop where stop is required. Installation of a nine aspect cab signal system on board NJT locomotives will provide the interoperability necessary to operate at higher speeds and closer headways in the Northeast Corridor.

Overview of the Conrail/CSX/Norfolk Souther Positive Train Control Platform Project (CR/CSX/NS)

In 1997, Conrail, CSX Transportation, and Norfolk Southern railroads received a grant from the FRA to develop, test and demonstrate an on-board PTC platform.

A determination was made that the design specifications would be object oriented with a standard bus. The objective is to develop an on-board platform which will accommodate inputs from any type of system governing the method of train operation (e.g., block signal systems, ATCS, ARES, PTS, ITCS, etc.) in order to facilitate interoperability.

The project was scheduled in two phases. Phase I was to complete the design specifications, issue a request for proposal (RFP) to define the system hardware, issue a RFP for a prototype, contract for prototype hardware and completion of the testing of prototypes. In Phase II, contracts have been signed for PTC design and prototypes and to conduct demonstration testing in the testbed between Manassas, Virginia and Harrisburg, Pennsylvania. The railroads have retained WABCO Railway Electronics to develop the design specifications in an open architecture. WABCO and GE Harris have been retained to develop the interoperable on board prototype to be tested in 1999. A contract for the design of PTC will be issued in 1999 and a demonstration will be conducted in 2000 contingent upon continued FRA funding.

Overview of the Enhanced Proximity Warning System (Train Guard)

Train Guard was conceived in a Burlington Northern labor/management safety committee in early 1993 as a means to make train crew members aware of other trains in their vicinity in non signaled territory. Following the merger of the Burlington Northern and Santa Fe railroads, further development of the proximity warning system was assigned to the BNSF's Technical Research and Development staff which has vigorously pursued Train Guard development. The BNSF retained Pulse Electronics (now WABCO Railway Electronics) to design and develop the system which is considered to be proprietary. Train Guard is similar to a proximity warning system installed in early 1977 on the Quebec North Shore and Labrador Railroad in Quebec, Canada by GE Harris.

Train Guard consists of an on-board computer, display, GPS receiver and mobile communications package (MCP) that transmits in the End of Train UHF bandwidth (450 Mhz). The OBC is provided with a track database that includes track curvature, grade, interlockings, signals, crossings and civil speed restrictions. The OBC uses GPS data, tachometer data and gyro data to locate to locate itself on the track database. Every 15 seconds, the MCP broadcasts the locomotive identification number, milepost location, speed and direction. Transmissions received from other trains are displayed showing the other locomotives' identifications, distance, speed, direction and age of the last radio communication received. The locomotive engineer is required to acknowledge the proximity of a new train, each signal location (not indication), and upcoming speed restriction. The OBC calculates braking distances to speed restrictions and other trains and initiates an automatic brake application if the train is not properly slowed.

Wayside communications networks are not required for Train Guard except in areas where MCP transmissions do not have coverage of 5 to 7 miles. In that event, wayside repeaters are installed to provide that coverage. The broadcasts of the MCPs on locomotives and repeaters are open loop.

No central office equipment is required to support Train Guard though a means is being developed to digitally update on-board databases including temporary speed restrictions. In the interim, temporary speed restrictions will be manually inputted into OBC by the locomotive engineer.

The BNSF is installing a Train Guard testbed between Barstow, California and Los Angeles, California, including a maintenance-of-way vehicle, to test Train Guard in the railroad environment. Train Guard is intended to be a low cost PTC system that fulfills the functionality requirements established and agreed to by the RSAC.

Train Guard is essentially a communications-based train stop system and for safety reasons still has to pass the hurdle of FRA acceptance as a PTC system.

Overview of the Communications Based Train Management System (CBTM)

The CSX railroad has embarked upon the development of a PTC system identified as CBTM. CSX has retained WABCO Railway Electronics to develop and test CBTM using the object oriented design concept and the CR/CSX/NS joint platform design. The CBTM design will be an open architecture.

CBTM will provide for the Railroad Safety Advisory Committee's (RSAC) core features in non-signaled territory: prevent collisions between trains; prevent overspeed of trains; and protect maintenance-of-way work zones from unauthorized intrusion by trains. CBTM will provide databases at wayside Zone Controllers that control train movements, issue movement authorities; issue targets for speed reductions, monitor switch positions; and protect maintenance-of-way work zones. The on-board computer (OBC) will calculate braking distances, calculate the far limits of authority, and initiate an automatic brake application at speeds above 8 mph when a violation is projected.

A testbed in non-signaled territory has been selected for testing CBTM concepts. The objective of CBTM is to design a system that meets the RSAC core objectives while providing an approach that permits the locomotive fleet to be economically equipped and interoperability achieved.

Overview of the Alaska Railroad Corporation Project (ARRC)

Early in 1998, the Alaska Railroad Corporation (ARRC) launched a program to install Precision Train Control™ (PTC) systemwide. PTC is a development of GE Harris, the System Engineer of the ARRC project.

PTC is the product of the UP/BNSF PTS project that is currently suspended. Like PTS, PTC has three major segments: the Locomotive Segment; the Communications Segment; and the Server Segment, which requires support of a computer-aided dispatching (CAD) system. Unlike PTS, PTC will include a Track Forces Terminal (TFT) for roadway employees. The TFT will provide location and tracking of maintenance-of-way on track vehicles and digital communications for obtaining and releasing work zones for the protection of roadway employees.

The ARRC has completed installation of a communications system to support PTC. A CAD system has been delivered and is scheduled for implementation in the first quarter of 1999. Deployment of PTC is scheduled for the first quarter of 2000.

Emerging PTC Projects

Overview of the Norfolk Southern Location System (NSLS)

NSLS is a recently emerging system for which specifications have not yet been completed or published. It is a proximity warning system that is being designed in-house on the Norfolk Southern railroad. NSLI is similar to Train Guard in that its concept is to inform train crew members about other trains in the vicinity. The NSLS design is proprietary to Norfolk Southern.

NSLS will utilize transponders located at each signal location that provide information to on-board computers about the location, distance to the next transponder and its location, and distance to the second transponder in advance and its location, maximum authorized speeds and civil speed restrictions. The on-board computer (OBC) will consist of an interrogator for reading transponders, a display and a mobile communications package (MCP) for transmitting data from the OBC. NSLS utilizes a tachometer to determine location between transponders. When a train passes a transponder, the locomotive identification, location, speed and direction will be periodically broadcast (open loop) by the MCP in the Norfolk Southern's End of Train Device VHS radio spectrum. The VHS broadcast is expected to cover about seven miles. When another train enters or is within the coverage of a train, its identification, speed and direction will be displayed to the locomotive engineer and acknowledgement required. When two opposing trains identify the same second transponder in advance, a safe braking distance is determined causing the OBC to initiate automatic brake applications on both trains.

The Norfolk Southern is continuing to develop the design of NSLS, including possibly displaying signal aspects on the display. NSLS is intended to meet the RSAC PTC objectives. However, like Train Guard, NSLS is considered to be a communications-based train stop system and is yet to be determined acceptable as a PTC system.

Overview of the AAR/FRA/Illinois Department of Transportation Positive Train Control Project (IDOT)

The FRA instituted this program jointly with the railroad industry and IDOT to design, test, build and install a PTC system on a segment of the Union Pacific railroad extending between Springfield, Illinois, and Mazonia, Illinois, a distance of about 120 miles. The industry agreed to participate with the FRA and IDOT through the Association of American Railroads (AAR) and its subsidiary, The Transportation Technology Center, Inc. (TTCI).

The objectives of the project are to develop, test and demonstrate PTC capabilities, including flexible block operations, interoperability and advance activation of highway rail grade crossing signals in a corridor with both freight and passenger service. In addition, the system must meet the safety objectives of preventing train-to-train collisions, enforce speeds and speed restrictions, and provide protection for maintenance-of-way employees and their equipment.

On July 15, 1998, TTCI issued a request for proposal seeking a System Engineer for the PTC program. The submissions of the offerors are being reviewed in preparation for selection of a System Engineer. The project is projected to require four years to develop, test and demonstrate.

COMPARISON OF THE PTC PROJECTS

The ATCS specifications were developed by the railroad industry with participation by suppliers and the FRA. The intent was to provide for both interoperability across railroad control systems and interchangeability between supplier products for such systems. The ATCS specifications set forth a range of communications-based applications including standardized communications methods, message protocols, logic to handle the exchange of messages, health monitoring, codeline replacement, work order reporting and positive train control.

The ATCS specifications provided a basis upon which railroads could build train control systems to meet the requirements for various operating conditions ranging from light density to heavy density lines. Four levels of ATCS functionalities were identified: Level 10 for light density lines included digital transmission of track warrants without enforcement; Level 20 included the functionality of Level 10 with train tracking and work orders but not enforcement; Level 30 included the functionalities of Levels 10 and 20 with enforcement; and Level 40 included the functionalities of Levels 10, 20 and 30 with control of switches and routing. Levels 10, 20 and 30 could be used with or without signal systems but Level 40 was specifically for traffic control type territory in which wayside signals could be removed and moving block operations implemented. A train equipped for either level of ATCS would be interoperable in the other levels to the extent the on board functionalities permitted.

All of the PTC projects have similarities to the ATCS specifications. Most, if not all, specify equipment and communications built to ATCS specifications. However, not all railroads have extensive data communications systems and among those that do, not all will support the ATCS specifications for standardized radio spectrum, communications methods, message protocols and logic for exchanging messages. Accordingly, each of the PTC systems under development have modified equipment or communications protocols to the extent they are exclusive to that project, conflicting with the objective of interoperability among the various systems.

A Matrix of PTC Systems (Appendix ___) identifies the characteristics of the systems in the 10 PTC projects. The matrix is composed of 14 categories containing data relative to each PTC system. Four categories, Architecture, Office Segment, Communications Segment and Locomotive Segment, identify the functionalities that set the systems apart from one another in terms of puissance and deficiency with regard to the safety of train operations.

The PTS, IDOT CBTM and ARRC systems will be centrally controlled from CAD systems while the ITCS, ACSES, Train Guard, NSLS, and NJT systems will be distributed systems even though installed in centrally controlled systems.

Two systems, IDOT and ARRC, have the objective to be a stand alone systems. Three systems, ITCS, ACCES and NJT are integrated systems. Four systems, PTS, Train Guard, NSLS, and CBTM are overlay systems. The CR/NS/CSX project is a developing platform technology that will be utilized in the IDOT and CBTM projects.

The ITCS, ACSES and NJT systems are most potent from the perspective of safety of train operations. These systems derive functionalites to enforce all train speeds and stop where stop is required from wayside signal systems that are designed and arranged to provide proper switch position, track and route integrity and spacing of trains. Protection of roadway workers is achieved by inputting work zone locations in databases on board the locomotive by radio in ITCS and via transponders in ACSES and NJT. The strength of these systems is integration with the wayside signal system where safety resides except for speed enforcement. The wayside signal indications provide a redundant overview to the locomotive engineer about the authority displayed in the locomotive cab. Further, the wayside signal systems provide immediate fall back to operations by signal indications in the event of failure of on board equipment. ACSES and NJT utilize proven technologies available off the shelf and, unlike ITCS, are not dependent upon an extensive communications network between trains and the control center or wayside. A weakness in the ACSES and NJT systems is ensuring transponder data is correct, especially in portable transponders used for the protection of roadway workers.

The PTS, CBTM and ARRC systems derive functionalities to enforce all train speeds and stop where stop is required from movement authorities issued to each train by CAD systems. These PTC systems require a communications network with high reliability and availability for transmitting and receiving data between trains and safety computers located in the central office and/or on the wayside. The strength of these systems lay in databases either on board and/or on the wayside that, in connection with GPS technology, provide precise train location for enforcement of all speeds and stop where a stop is required. Protection of roadway workers is accomplished by inputting the location of work zones and their associated speeds into the databases. In the CBTM system, the requirement for hard copy of block authorities provide a redundant overview of the authority displayed in the cab. A weakness of the PTS and CBTM systems is that in signaled territory, signal indications do not provide a reliable redundant overview of the authority displayed in the cab. The CBTM system does not enforce speeds or stop commands at speeds below 8 miles per hour. Failure of the on board equipment in the ARRC system, and PTS in automatic block signal or non signaled territory, will require fall back operations to copying and repeating mandatory directives for movement of the train.

The Train Guard and NSLS systems are proximity warning systems that derive functionality to prevent train-to-train collisions from the reception of data transmitted by other trains in the radio spectrum. They are locomotive on board systems extraneous to existing methods of operation or wayside signal systems, an irrelevancy precludes enforcement of stop where stop is required, e.g., at the end of the limits of authority or a wayside signal aspect indicating stop. Wayside signal indications will provide redundant support of data displayed on board for the movement of trains but not for the protection of roadway workers. No such redundancy will exist in non signaled territory. The weakness of both systems is the dependence upon antennas on locomotives that may as a result of damage or deterioration unknowingly degrade transmission and reception of train location data in an open loop broadcast.

The IDOT system will derive functionalites to enforce all train speeds and stop where stop is required from movement authorities issued by the CAD system and central safety computer of which the wayside traffic control signal system will become an integral part. The system will require a communications network with high reliability and availability for transmitting and receiving data between trains and safety computers located in the central office or on the wayside. The strength of this system is complete integration with the wayside signal system where safety resides to provide proper switch position, track and route integrity and in databases either on board and/or on the wayside that, in connection with GPS technology, provide precise train location for enforcement of all speeds and stop where a stop is required. Protection of roadway workers will be accomplished by inputting the location of work zones and their associated speeds into the databases. Interoperability with other PTC systems will increase the vigor of the IDOT system. The development of flexible block operations, desirable for increased track capacity, will result in the removal of wayside signals. Elimination of the wayside signals are an economic benefit but exposes a weakness by excluding redundant support of information displayed on board the locomotive. Special requirements will be necessary to mitigate hazards associated with train movements experiencing failure of on board PTC equipment since there will be no wayside signals in essentially a traffic control system.

Benefits of Adding PTC to Existing Methods of Operation and Signal and Train Control Systems.

The initial concept of optional utilization of conventional signal and train control systems has evolved to development of PTC systems that augment existing wayside systems which still have many years of useful life. The current initiatives are to maintain the safety features and business benefits of existing systems while adding functions that cannot otherwise be obtained, particularly enforcement of all speeds and absolute stop where a stop is required. Such functions will reduce the human factors that contribute to train collisions, overspeed type derailments and casualty to roadway workers while providing for more efficient train management and track utilization.

It is evident that each current method of train operation and operation in each type or combination of signal and train control system is heavily reliant on human performance to properly issue and copy train orders, control train speeds and stop where a stop is required. PTC systems have the capability of systematically identifying the location of a train in relation to current speed requirements, speed restrictions in advance, and the point were a stop is required. The systems are capable of enforcing all speed limits and most will enforce all stop commands. Results of actual field tests of several PTC projects indicate that the systems have the potential to intervene before incorrect train orders or excessive speed imperil a train movement or a train passes a point where a stop is required.

PTC functionality of precisely identifying the location of a train provides the means for the protection of roadway workers. Inputting the location of work zones for roadway workers into the system affords roadway worker protection by enforcing train speeds to that prescribed for the work zone or, when necessary, enforce stopping before a train enters a work zone. This procedure will eliminate dependency upon train crew members to properly control the speed of a train in a work zone and ensure that a train cannot enter a work zone until authorized by the foreman in charge. The Train Guard and ARRC systems plan to provide tracking of on-track vehicles used by roadway workers. The Train Guard, NSLS and ARRC systems will implement a PTC terminal by which roadway workers can communicate with trains and the central dispatching office.

The application of any PTC system to the various methods of operation and wayside signal systems will elevate the existing level of safety for train operations and roadway workers. The centrally controlled systems have potential to achieve the most business benefits, e.g., traffic planning, train pacing, plant utilization, improved productivity in labor, fuel and equipment, etc. However, most PTC systems to some extent will provide means to achieve higher capacity in existing plant and certain economic benefits.

ITCS, ACSES and NJT systems are designed essentially to be installed where the method of operation is by signal indications to provide for closer headway of train movements at higher speeds. These systems will enforce the speeds prescribed by each wayside signal indication while safely permitting higher speeds than that for which the wayside systems were originally designed. The ability to increase track capacity without extensive plant expansion is of significant economic benefit, especially in corridors with limited rights-of-way. The ability to increase train speeds without modifications in the existing wayside system, also a significant economic benefit, improves throughput with resultant increased ridership on passenger trains and improved customer service.

The PTS, CBTM and ARRC systems are potentially capable of being installed in signaled or non signaled territories. Installation of these systems in signaled territory may or may not materially impact the existing method of operation except for enforcement of speed and stop commands PTS and ARRC systems will digitally transmit track warrant movement authorities to computers on board locomotives, eliminating the requirement of reading and repeating each authority which is both a safety and economic benefit. All three systems will promote expeditious handling of train operations by providing real-time information for better decision making. In non signaled territory, the systems will provide for closer headway of train movements with resultant increased track capacity.

The proximity warning systems, Train Guard and NSLS, are locomotive on board systems capable of being installed in signaled or non signaled territories. Neither system affects the existing method of operation nor do they require an extensive communications network for support. Train Guard is provided with an on board database and location system that precisely locates a train for speed enforcement. NSLS determines speed enforcement from data obtained from transponders located in the track structure and an on board location determination system. However, a train equipped with either system will enforce all track speeds and safe braking distances between other trains or roadway workers detected within proximity capability of the on board communications system.

The IDOT system will be developed in traffic control territory and progressively incorporate all of the traffic control functions into the PTC system except for wayside signals in areas of flexible block operations. The system will replace operations by signal indications with operations by PTC, a novel method of train operation. The IDOT system will provide opportunity to achieve maximum business benefits while providing enforcement of all train speeds, stop where stop is required and protection of roadway workers.